# TES ON THE RESISTANCE OF PAPER TO TEARING

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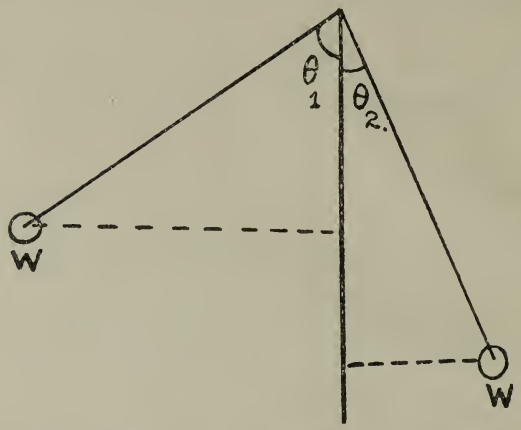
The physical testing of papers from the standpoint of durability has, hitherto, been confined to determinations of tensile strength, bursting strength, and, in some cases, resistance to folding or creasing. Of these, tensile strength determinations alone can be considered as scientific tests. Bursting strength cannot be lucidly explained, the instruments available for its determination are subject to an appreciable personal equation, and the ease with which they are used has been responsible for the introduction and fostering of a comparatively unworthy fetish throughout the paper trade in this country and the United States. Our scientific knowledge, therefore, of the durability of papers has been somewhat limited, for one of the most important factors in the standard of paper has not been capable of accurate measurement—the resistance to tearing. To the user of paper, the resistance to this form of strain is possibly more important than its resistance to any other. Paper buyers all the world over perform the same rites when examining a sample of paper, they look at it and through it, feel it, shake it, twist it, and, finally, religiously proceed to tear it. From the subsequent behaviour of the buyer, the salesman gauges his prospects of effecting a sale. Evidently the question of tearing is worthy of the consideration of all papermakers. That the empirical method of testing referred to should be placed on a scientific basis is greatly to be desired.

It has long been realised that the need for apparatus for accurately determining the resistance of paper to tearing was great, and much work has been done with the object of devising a suitable instrument. One instrument, the Thwing Tearing Tester, has been known for some considerable time, but is too delicate and complicated for general use. Recently, we have had brought to our notice an instrument which is accurate and simple in design and method of use—The Elmendorf Tearing Tester.

This instrument, invented by Mr. Armin Elmendorf, of the U.S. Forests Products Laboratories, and introduced into this country by Major Renold Marx, fully meets the requirements of the paper trade as an instrument of precision for the purpose above mentioned. The fact that it is the only existing instrument by means of which we can further our knowledge of tearing is, I think, sufficient justification for dealing with it at some length in this paper, and a brief description of the design, method of use and theory of the instrument will, no doubt, be acceptable.

The theory of the instrument is comparatively simple.




A pendulum of weight W is suspended at 0, and swings from an initial angle $\theta_1$, through the vertical, to a final angle $\theta_2$.

The initial height of W above its lowest position is $L—L\cos\theta_1 = L(1—\cos\theta_1)$, and its final height is $L—L\cos\theta_2 = L(1—\cos\theta_2)$.

Further, $WL(1—\cos\theta_1)$ = potential energy of the pendulum in its initial position, and $WL(1—\cos\theta_2)$ = potential energy of the pendulum in its final position.

The difference between these two expressions is equal to the work done in making a tear of r inches plus the constants of the instruments, i.e.,

$$WL(\cos\theta_2 \quad \cos\theta_1)—Sr + K + C\ (\theta_1 + \theta_2)$$

Where S —the resistance to tearing.

$C(\theta_1$ plus $\theta_2)$—the friction of the pointer.

and K —the energy absorbed by the pointer during the first half swing.

In the above equation, r and $\theta_1$ are fixed in manufacture and W, L, K, and O are determined for each instrument, so it is easily seen that S, the resistance of the sheet to a definite length of tear depends solely on the difference between $\theta_1$ and $\theta_2$, which difference is automatically measured by the pointer, and the scale is graduated to read directly the resistance in grams.

The interest in the question of tearing is divided between the papermaker and the user, and as most of the points common to both can be more readily dealt with from the standpoint of the papermaker. we will consider them first.

The papermaker is primarily interested in all methods of physical testing as an aid to mill control. He is desirous, by means of routine tests, of controlling the running of his plant to the best advantage, and maintaining a certain standard of quality peculiar to the particular grade being made. The value of any particular method of testing being dependent on the amount of knowledge derived from its execution, and if the efficiency of

isolated units of the plant can be determined by a system of testing, this value is considerably enhanced.

The principal factors which determine the strength or durability of a paper of any given substance are nature of furnish, length of fibre, degree of beating, the amount of gelatinous adhesive matter present and the arrangement of the fibres in the sheet. The furnish for any particular grade is determined by requirements and experience; length of fibre, degree of beating, and adhesive matter are ordained by the beaterman, and scientific control of these factors during the beating process is now to a great extent possible. The remaining factor, the arrangement or disposition of the fibres is dependent on, the running conditions of the paper machine, and in this connection tearing tests can be made use of to great advantage.

I would endeavour to show how determinations of the resistance to tearing help in controlling what I have termed the Mean Disposition of the fibres in a sheet.

We may consider the form of the fibres in a machine-made sheet of paper to consist of a number of short straight lines. No whole fibre will necessarily present this ideal condition, but we are concerned with almost infinitesimal portions of fibres at any particular point.

Then, if we refer to the machine-direction as an axis, the fibres will be arranged at varying angles to this axis. We know that there is more tendency on the part of the fibres to be parallel to the machine-direction than at right angles to it.

Now, as a tear is made in the machine-direction it is easily seen that the resistance will greatly depend on the angle at which the portions of fibre in their turn meet the tearing force; the greater the angle, between the limits 0° and 90°, the greater the resistance and, hence, the force required to overcome it. The Elmendorf Tearing Tester acts as an integrator in giving the sum of all the individual amounts of work done in overcoming these successive resistances. Similar remarks apply to a tear made in the cross-direction, the axis of reference alone being different. For the same sheet, it follows that the difference between the machine-direction tearing resistance and the cross-direction tearing resistance can be accounted for by the relative disposition of the fibres to the two axis, other "strength giving" factors being identical in both cases. For convenience, the ratio machine-direction tearing resistance to cross-direction tearing resistance is calculated as a percentage. Thus equal values would give a ratio 1 : 1 or 100 per cent.

From the theoretical considerations above, it will be seen that a good handmade sheet, in which there is no tendency for the fibres to lie in one particular direction, should give almost equal values in any direction. This is found by experiment to be the case. Similarly, a machine sheet will give machine and cross-direction values more nearly approximating equality the nearer the conditions on the machine approach perfection.

I consider 80 per cent. to be the dividing line between good and bad tearing resistance ratios. If less than 80 per cent. is obtained the running conditions of the paper machine should be carefully investigated. The machine may be running at a greater speed than is warranted by the nature of the "stuff" and the substance of the paper being made, or, the amount of "shake" at the wet-end of the machine may be insufficient. One or the other of these factors is usually the cause of poor tearing resistance ratios. A little experimental work in this direction is apt to show that a machine has been running for some considerable time at a low degree of efficiency. I do not suggest that "freak" speeds or "shake" should be employed as a means of rectifying poor results, but that an efficient combination may be arrived at by means of a little experiment. To emphasise the importance of tearing resistance ratios, I would suggest that a ratio of say, 60 per cent. means that only 60 per cent of the fibres in the sheet are being used to full advantage, the remainder are practically wasted. The papermaker, by applying the results of routine tests in the way suggested is able to reduce this waste to a minimum.

As an example, a tissue of 6¼lb. D.C. being made at 84 feet per minute gave a ratio of 55.5 per cent., this was considered unsatisfactory, and at a speed of 68 f.p.m. the ratio was increased to 70.9 per cent. The speed being low even for the notorious speeds of tissue machines, the "shake" was altered and finally a ratio of 85 per cent. was obtained at 75 f.p.m.

In addition to the above considerations, the determination of tearing resistance has a point of considerable interest to papermakers and merchants alike. We have been dealing at some length with the importance of the relation between individual tearing resistances in the machine and cross-directions respectively, but it is natural that a high ratio is of no satisfaction unless it is obtained from individual values which are themselves satisfactory. The values obtained in tearing resistance determinations are measures of the capability of the papers under test to withstand a form of strain common to the life of all papers in practical use, and the importance of the values from this point of view is commensurate with the number of times the average "piece of paper" is called upon to resist tearing. There should be, for every grade of paper, a standard machine-direction tearing resistance and a corresponding cross-direction tearing resistance. No useful purpose would be served by attempting here to formulate standards. It is the work of technologists in the respective branches of the industry. The comprehensive nature of this work, and the impossibility of dealing with it in this short paper may be estimated from the fact that I have been tabulating results on a very limited range of papers for almost a year, and have not yet arrived at any definite standards.

Comment may be raised on the entire absence of statistics in this communication. I will explain this shortcoming. The choice lies, in compiling a short paper, between giving all statistics, a

few, or none. The first alternative is uninteresting, the second useless, hence, there are no tables in this paper.

I have endeavoured to stimulate the interest of members of the Technical Section in the general principles of the subject, and have also attempted to indicate its importance to papermakers and all who are concerned in the buying and utilisation of the papermaker's products.

I take this opportunity of making a suggestion which, I hope, will be of interest to the members of the Section.

One of the objects of the Technical Section is Research. The average paper technologist cannot spare the time to engage in research on profound subjects such as hydration. Much useful work, however, could be done on the question of tearing without undue interference with routine work. The routine work, in fact, could be made research work at the same time. I would suggest that technologists representing each branch of the industry be asked by the Research Committee to carry out experiments and furnish information on their own particular grades. The information could then be co-ordinated with a view to establishing definite standard tearing resistance values. Work could also be done on the application of tearing tests to mill-control, the remarks I have made in this connection still remain to be proved or disproved.

More fundamental work on the nature of tearing would also be enlightening. A slow-motion film of a tear taken under medium or high powers of magnification would indeed be interesting.

Simple experiments, judiciously organised, would, I feel sure, be extremely beneficial to the whole of the industry, and I see no reason why the Manchester Division should not lead the way in launching a simple and efficient scheme to this end.

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## DISCUSSION.

Mr. **Hubner** said he felt that the term tearing strain, although quite correctly applied to tests made on the Elmendorf apparatus, might lead to confusion, because it has hitherto been frequently, although wrongly, applied in place of tensile strain.

He suggested the use of "ripping strain," which is more distinct, in place of it

He had considerable experience, during and after the war, in studying the ripping strain of cotton fabrics as compared with the tensile and the bursting strain. The ripping strain was, in many cases, of greater importance than the tensile strain.

He had found that the tensile strain was not directly comparable with the ripping strain.

In two papers which he read before the Society of Dyers and Colourists, he showed that careful bleaching, for instance, hardly affected the tensile strain of fabrics, whilst it affected the ripping strain very appreciably.

The application of metallic salts and of soap did not affect the tensile strain detrimentally. In some cases, as a matter of fact, it showed a distinct increase. The ripping strain, however, in the case of metallic salts was decreased, whilst with soap it was considerably increased.

He felt that there was a distinct similarity between fabric tests and paper tests, although the manner in which the ripping strain was applied to fabrics differs from that applied to paper.

In order to imitate the ripping of fabrics as applied by hand, a slit was cut into the fabric, the two ends were then fixed in the clips of a Schopper machine, and the strain was applied in such a manner that the warp or weft threads, respectively, of the fabric were broken one by one. About 40 to 50 readings were taken from each sample, and it was found that perfectly reliable results could be obtained by this method.

In testing the ripping strain of a paper by hand, once the rip had been started, the pull is applied downwards, i.e., practically speaking in the plane of the sheet.

In this method of ripping it is, therefore, not simply a question of tearing the fibres only, but in most cases of splitting the sheet into layers (his opinion was supported by one of the speakers, who very aptly described the typical ripping of a paper as " skinning ").

A comparison of the method of ripping on the Elmendorf tester showed that there was a considerable difference between this method of ripping and the commonly practised method, i.e., ripping by hand.

There were many factors which will influence and determine the ripping strain of papers, and he believed, as in the case of fabrics, the results will not be directly comparable with the tensile strain.

Some of these factors were:—

> The length and the strength of the ultimate fibres; the amount and the nature of the sizing; the position of the fibres in the sheet in relation to the machine and the crossway; the degree of felting; the amount and the type of loading material added; the method of calendering, etc.

He felt that something should be said with regard to the use of mean or average figures when discussing the strength of papers.

From the paper sellers' point of view it may be convenient to deal with average figures, but when it was a question of applying the results of strength testing to mill control, average figures, in his opinion, were misleading.

Useful deductions could only be made when the highest and the lowest results are available.

The Elmendorf tester was without doubt of great interest, but, as Mr. Potts pointed out in his paper, a very large amount of work will have to be carried out in order to ascertain whether the results obtained in testing different qualities of papers are comparable.

If the instrument was to be chiefly employed for mill control every user will, no doubt, find out its suitability for the particular classes of paper which he manufactures. If, on the other hand, it was suggested that the instrument should be adopted by both the paper maker and the consumer, careful and systematic standardisation of the instrument becomes essential.

Although a considerable number of comparative ripping tests have been carried out on a very delicate and accurate Schopper machine and on the Elmendorf tester, he wished it to be clearly understood that it was not his intention to criticise the tester, but to submit a few of the figures obtained for the consideration of members, because he hoped that this would lead later on, when a wider experience with the tester has been gained, to a uesful exchange of views.

The papers tested were fixed in the clips of the Schopper machine in such a manner as to closely imitate ripping by hand.

The pawls on the weighted lever were fixed in order to allow the lever to swing back freely when a rip took place.

From 30 to 40 readings were taken for each test.

In order to allow a comparison between the results obtained on the Schopper machine and those obtained on the Elmendorf tester it was necessary to give the mean values, but the highest and the lowest readings are also given (in brackets).

The first test was made on a writing paper, weight 84.2 grms. per square meter, thickness 0.1 millimeter. This gave on the Schopper machine:—

| Machine way. | Cross way. |
|---|---|
| 37.4 (30-50) | 47.2 (33-54), |

Direction of tear in Schopper shifts whole time.
and on the Elmendorf (six strips):—

69.5 (67-72) 82 (76-88).

Another test was made on a cartridge paper, weight 101.5 grms. per square meter, thickness 0.152 m/m.

Three series of tests were made, i.e., two (A and C) taken near the deckle edge and the third (B) taken from the centre of the web.

SCHOPPER:—

| | Machine way. | Cross way. |
|---|---|---|
| A. | 59 (48-88) | 71 (63-84) |
| B. | 59 (51-68) | 71 (50-86) |
| C. | 62 (53-78) | 69 (54-85) |
| Mean. | 60 | 70 |

ELMENDORF (Two strips):—

| | | |
|---|---|---|
| A. | 39 (39-39) | 75 (65-86) |
| B. | 58 (52-64) | 63 (63-63) |
| C. | 53 (45-62) | 63 (55-71) |
| Mean. | 50 | 67 |

As in this case two papers in place of six had to be torn on the Elmendorf tester the results given should be multiplied by three. It will, therefore, be seen that these results when compared with those obtained by tearing the writing paper on the Elmendorf tester are very much higher.

Another test was made on an M.G. cap, weight 48 grms. per square meter, thickness 0.074 m/m.

Three sets of tests were made as in the case of the Cartridge paper, and six papers were torn simultaneously on the Elmendorf tester. The results obtained were as follows:—

SCHOPPER:—

| | Machine way. | Cross way. |
|---|---|---|
| A. | 36 (26-50) | 42 (30-60) |
| B. | 38 (24-46) | 47 (30-67) |
| C. | 35 (24-46) | 50 (32-72) |
| Mean. | 36 | 45 |

ELMENDORF:—

| | | |
|---|---|---|
| A. | 53 | 82 |
| B. | 72 | 85 |
| C. | 53 | 97 |
| Mean. | 59 | 88 |

I have also done tests force-length.

The results obtained by testing this paper are comparable with those obtained by testing the writing paper.

Finally a hand-made paper, weight 129.5 grms. per square meter, thickness, 0.171 m/m. was tested. Two sheets only were torn simultaneously on the Elmendorf tester, and the results given have, therefore, to be multiplied by three.

SCHOPPER:—

| Machine way. | Cross way. |
|---|---|
| 104 (90-116) | 108 (94-122) |

ELMENDORF:—

72 (216) 74 (222)

With the exception of the Cartridge paper the results obtained on the Elmendorf tester are approximately twice as high as those obtained on the Schopper tester.

He submitted these tests in order to support the suggestion made by Mr. Potts that it is of the utmost importance to test the apparatus thoroughly and systematically on all classes of papers. It would also be of importance to ascertain whether there are any definite relations between the tensile, the ripping, and the bursting strain of papers.

A systematic investigation such as this will, in his opinion, not produce the most satisfactory results if carried out independently, either in the

mill or in the laboratory. The closest co-operation between the two is essential.

In order to obtain results which are both accurate and comparable, he suggested that the testing of all the papers submitted by different mills should be carried out by one, or better still, by two independent investigators.

Mr. J. H. Mowat said he regretted Mr. Potts had not given them a definition for tearing strength. One requires this definition in order to be in a position to criticise the paper.

This was his first actual acquaintance with the Elmendorf, and he could not agree that its action resembled that of the tear given by the practical man, who holds the sheet in the left hand, which remains stationary, and tears the sheet down with his right, giving a single tear.

The Elmendorf gives a double tear, and its action appears out and down, not straight down as the papermakers tear it.

Mr. Potts does not like the Mullen test, but for general routine work it was difficult to better that test. If he were required to control mill processes by means of an instrument he would still incline to the Mullen.

Mr. Arnot said that previous speakers had voiced some of the things which were in his own mind to speak about, but that the meeting would perhaps pardon a little repetition. He enquired whether the tearing strength was recorded as for the whole six strips or was reduced to the equivalent of one strip, and called in question the possibility of getting accurate results in this way. It appeared from the remarks of previous speakers that the figures were reduced to strength for one sheet, but it appeared to him that one still had to deal with not one tear, but two, and that, therefore, the machine should be called the Double Tear Machine, just as Schopper folding machine is called the Double Folding Machine.

The figures which Mr. Hubner quoted supported his contention that accurate results were not obtained. If Mr. Hubner's figures for the Elmendorf tester had been consistently double those for the results got on the Schopper break tester when used for tearing, he would have said that the machine was a very good instrument, but in cases when six sheets could not be used the results were very divergent, and either the instrument was wrong or there was something wrong with the reduction factor.

He took exception to the use of the word "durability" in the paper. Durability is not the same as strength. He remembered visiting the Metcalf Library in Calcutta to consult an ancient work, and there finding many of the volumes in a deplorable condition due to the ravages of microscopic plants and of the insects, although the papers originally were doubtless very strong. In considering the tearing of paper we are dealing solely with the question of strength.

He was much surprised to hear from Major Marx that the tests were made without any reference to the atmospheric moisture. That was one of the most important conditions in all such tests, and it was well known to every one present that the standard adopted by the German Materials Testing Office is 65 per cent. of saturation. All tests must be carried out at this normal standard, which is quite easily maintained with the aid of the proper apparatus. He had not had the pleasure of using the Elmendorf tester, but had made thousands of tests both on the Schopper strength tester and on his double folding machine; in fact, he ordered for the firm he was then serving one of the very first folding testers made. At that time they made many hundreds of tests under every possible variation of temperature and moisture. to find out just where they were, and not only in the official testing offices, but in the mill laboratory, the standard moisture condition must be strictly observed. Again, it is of no use to fetch the sample from the machine room and test it; it must be allowed time to acquire the normal moisture from the air of the laboratory before the tests are applied. Of course, all scientific work must be done under strictly standardised conditions.

It was necessary in the interest of progress that a wrong impression regarding the Schopper break tester should be removed. Mr. Potts stated that he had been unable to obtain reliable readings when testing tissues on the Schopper machine, mainly because the readings were too low on the scale, or because the break took place almost as soon as the pull was applied. He had ascertained that the instrument Mr. Potts used was the ordinary one for the usual ranges of paper, and that Mr. Potts. was not aware that a special machine is made for the sole purpose of testing tissues and papers of that class.

In the manufacture of what are known as "*normal*" papers for the German Government, the physical properties of the paper are closely followed throughout the whole run on the machine, by means of testing instruments, and for more than a quarter of a century the preparation of the stuff and the running of the machine have been controlled in the way that Mr. Potts now suggests as being possible because of the advent of the Elmendorf paper tearing machine.

He heartily agreed that research such as Mr. Potts desired is necessary; moreover, he felt sure that some definite relation will be found to exist between the tearing strength and the breaking strength taken in conjunction with the folding properties of a paper. It is very desirable to have this relationship discovered, when the physical testing of paper will become more than ever standardised, systematised and utilised.

**Major Marx** emphasised the necessity for taking into account humidity conditions when carrying out strength tests of any nature on paper. This applied whether the tests were tensile, tearing, stretch, folding or of any other description. He produced some curves showing effect of humidity on the tearing strength, and also on stretch and folding properties of a few papers. (Figs. A, B.) It frequently occurred that papers were tested in the mill under one set of humidity conditions, and after they had left the mill tested by the purchaser under entirely different conditions. Unless the marked effect of humidity were taken into consideration such tests might frequently react to the detriment of the mill.

Dealing at the request of the Chairman with the points raised by Messrs. Hubner and Arnot, the speaker noted that Mr. Arnot had qualified his remarks by saying that he had not used the Tearing Tester, while Mr. Hubner said he had only had one in use for a short time. Nevertheless, their criticism was appreciated. He had listened with much interest to Mr. Hubner's remarks on the tearing or ripping of fabrics, but considered that the ordinary papermaker's tear differed from what Mr. Hubner had described as the ripping of fabric. In the speaker's view the Elmendorf Tester did undoubtedly effect something closely approaching the papermaker's tear. He found the same difficulty as other speakers in suggesting an exact definition for such a tear, but, however one defined it, the instrument always carried out the tear in exactly the same manner, so that the figures which it gave were always comparable with one another. So far no uniform relationship had been found to exist between tearing strength and other strengths, such as breaking and bursting strength, and it was not easy to believe that such a general relationship could exist.

On the question of average figures, the speaker held that it was quite impossible to avoid the use of averages. In order to do so, it would be necessary to measure the variation in tearing strength of a sheet of paper from one fibre to the next, and take the maximum and minimum values. He felt sure that Mr. Hubner would not suggest that as a practical proposition. The highest and lowest values could, in the nature of things, only be exceptional, and each would probably only occur once in any series of tests, and possibly then as the result of an accident. If taken into serious consideration they should be considered in their relation to the whole of the rest of the values obtained. Questions of paper testing were intimately bound up with the nature of the papers under test, and the uses for which they were intended. Clearly a good sheet of ledger paper would need to fill requirements different from a sheet of news, or, again, from a Manilla wrapping. Thus one would expect to judge the strength

properties of any sheet on the basis of a standard set up for this particular class of sheet.

He was very glad that Mr. Hubner had referred to a comparison between tearing tests on an Elmendorf Tester and some tests which had been carried out on the Schopper machine. He had also carried out some tests of this kind on an electrically-driven Schopper machine, and had come to the conclusion that the tests, as Mr Hubner described them, did not afford a proper comparison with the Elmendorf Tearing Tester, although they might possibly serve as a rough guide. In the first place, the Elmendorf Tearing Tester was so calibrated that if a sheet of paper were held in the fingers of both hands and torn, the force exerted by each hand being, say, 200 grams, then the Elmendorf machine in testing this sheet would record the tearing resistance of the sheet as 400 grams; whereas if the same test could be carried out accurately on the Schopper machine, which it could not, the latter would record 200 grams. It appeared to him that to describe the tearing resistance under these conditions as 400 grams was more logical

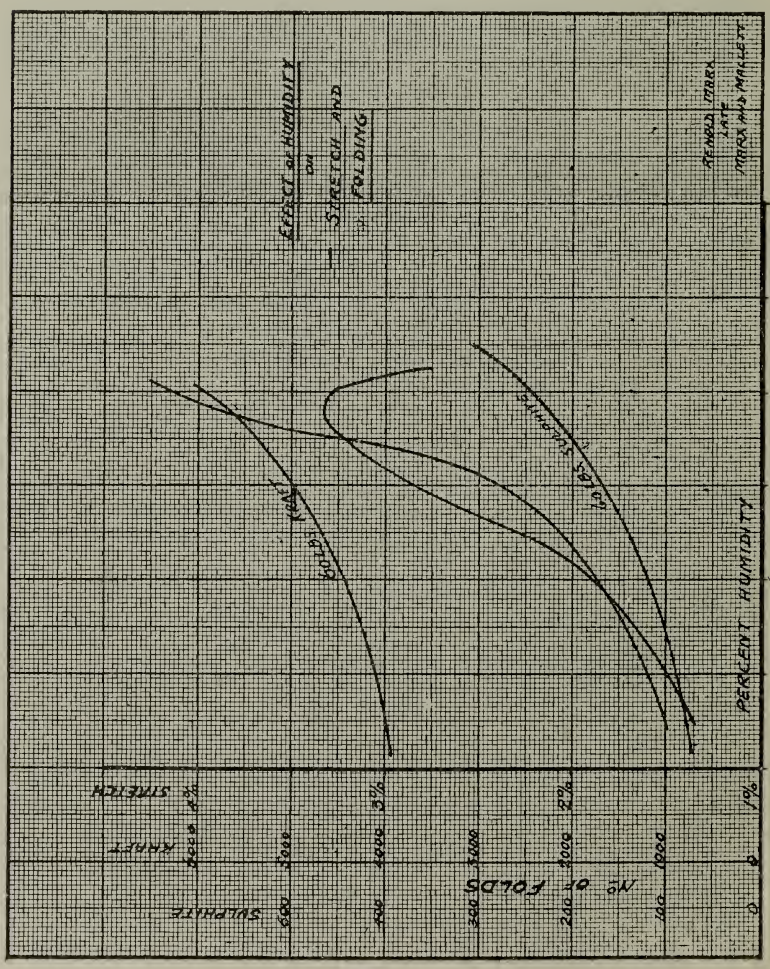


Fig. A.

than to give it as 200 grams, but the matter was one of opinion, and he would like to ask those present for their views on the subject.

In either case it would not affect the graduations of the Elmendorf machine.

The reason why results obtained with the Schopper machine would not compare was not difficult to understand if one had attempted to carry out such tests on the Schopper machine. Very large fluctuations would be met with, and it would be necessary to take a great number of readings during the progress of each tear and to analyze these readings most carefully in order to obtain results of real value. This would be most difficult if not possible. Mr. Hubner had managed to find some kind of rough

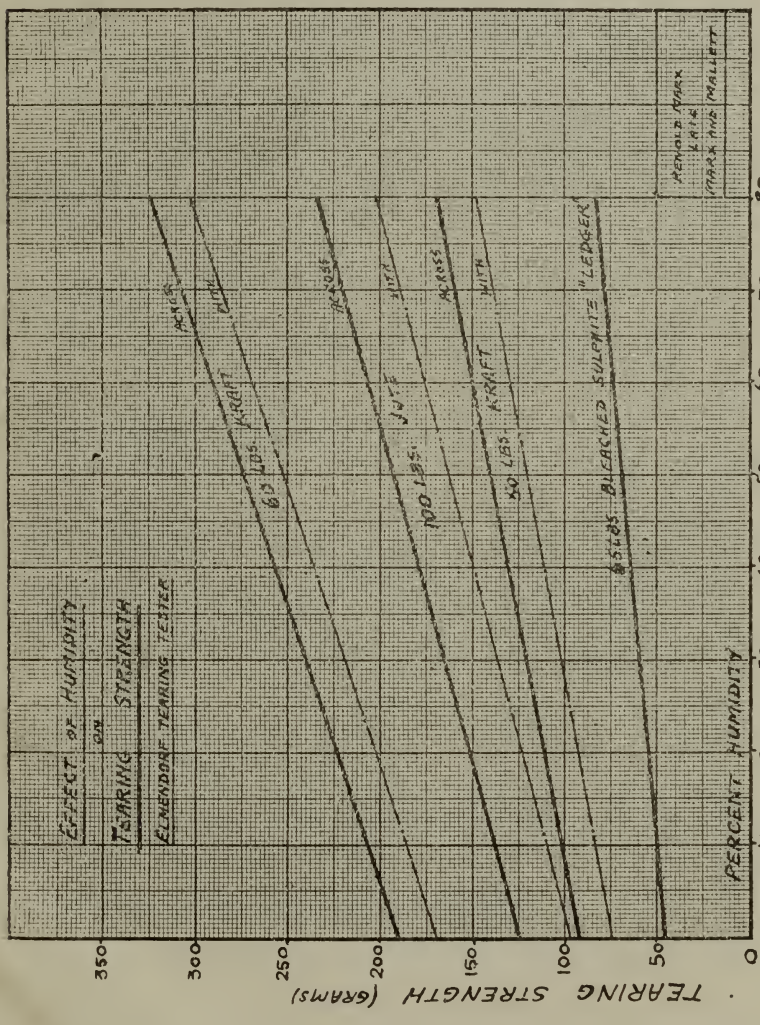


Fig. B.

relationship, and, excepting in the case of one paper, his Elmendorf results were approximately twice as high as his Schopper results. This was precisely what he (the speaker) would have expected to find, and corresponded with what he had just said.

So far as his own tests, and those of a considerable number of users, had shown, the personal factor did not appear to affect results, and that practice with the 200 instruments already in use had shown that they gave steadily uniform results. As regards the question of a single or double tear, it was just as easy to make a single tear if this was preferred, but apparently the machine gave proportionate results irrespective of whether a single or double tear were carried out.

Mr. Potts said the discussion had further emphasized our ignorance on the question of tearing, and the urgent necessity for research work. Several points raised had been already dealt with by subsequent speakers, and he would confine his replies to those remaining.

With regard to humidity and its effects on tests, it is naturally to be expected that note should be taken of all conditions when making tests; yet, as the result of very careful experiments over a great number of tests, it was found that tests were practically unaffected by such small changes of humidity as occurred in a laboratory, and the changes had to be almost abnormal before any appreciable effect on the results was noticed.

He had the original curves referred to by Major Marx, and some he had himself prepared, and the connection between substance and tearing strength was undoubtedly very interesting, but at present rather abstract. Further work would no doubt establish a clear conception of this connection, if any.

While agreeing with Mr. Hubner that the term "tearing" had been badly used in the past, he did not see any advantage in changing it to "ripping." Mr. Hubner's results with balloon fabrics were most interesting, and a very useful adjunct to the general study of tearing. He had been privileged to see quite a number of these tests carried out at the College of Technology, and agreed with Mr. Hubner that the connection between paper and fabric from the physical standpoint was very close.

Sizing, loading and calendering exercised a great influence on the tearing of a sheet of paper, as did the machine room atmosphere. Calendering properly done under perfect conditions increased the strength and durability.

Mr. Mowat had asked for a definition of a tear. If tearing was to be standardised, then the official definition of a tear would have to be decided first. At present it was very difficult to give a definition in simple language which would serve as a standard.

Mr. Arnot's remark that the machine was a double-tear device was incorrect. The Elmendorf tester gave a result sufficiently accurate to be considered as for one continuous tear of a definite length. The fact that it was divided into twelve separate lengths did not affect the accuracy of the results obtained. With reference to the remark that strength and durability were not identical, he quite agreed that this was the case, but believed that the tearing resistance value was to a great extent a measure of durability, though not of its resistance to insect ravages such as Mr. Arnot had mentioned. That was another phase of the question altogether.

He agreed with Mr. Hubner that, in the event of organised research work being done, it would be desirable to have all the tests done by one person, but the amount of work involved would make this almost impossible, and he suggested one investigator for each grade for the most important, and a little more liberal allotment of work for the less important grades.

In conclusion, he thanked the meeting for the way the paper had been received, and trusted that the discussion had aroused interest in the subject, and that further work would be done.